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Original Article

The usefulness of the Stroop effect during sorting movements -Aging differences in microslips and Stroop interference rate-

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Abstract

This study aims to verify the differences in task execution according to oral and manual classification, the correlation between required time and the number of microslips, and the difference in the Stroop interference rate among young people and middle-aged people. There were 16 targets in Experiment 1 (21 to 55 years of age) ; and in Experiment 2, 30 targets in the young group (ages 20 to 39) and 30 in the middle-aged group (ages 40 to 59) , all of whom were normal, healthy adults. We used four varieties of 16 classification cards, and classified each. In Experiment 1, we calculated the required time for the oral and manual tasks and the Stroop interference rate; and in Experiment 2, we calculated the required time during the manual tasks, the Stroop interference rate, and the number of microslips, and compared the oral and manual tasks, as well as the young group and the middle-aged group. The Stroop interference rate was significantly higher during the oral tasks than during the manual tasks ($p < .05$) . Comparing the young group to the middle-aged group, the middle-aged group had a significantly higher Stroop interference rate in both oral and manual tasks than the young group ($p < .05$) . The middle-aged group's number of microslips increased significantly compared to the young group ($p<.05$) . As for the correlation between the required times and the number of microslips, a high correlation was shown in the 4 varieties of classification cards ($p < .05$) . In this study, the Stroop interference rate on choice reaction was higher in oral tasks than in manual tasks. Furthermore, oral reaction times were slower than manual reaction times in both simple and choice reaction tasks. It was indicated that the number of microslips increases with the delay in time, and a correlation between the number of microslips and time was shown.

Key Words

Stroop task, Stroop interference rate, Microslip, Manual task, Aging

Introduction

We are exposed to various types of information from our peripheral environment, and we act while selecting the necessary information. However, it is difficult to process information while simultaneously selecting numerous pieces of information [1-2] . Executive function has the ability to plan, inhibit, and control attention and actions [3] .

In recent years, it has been indicated that executive function disorders contribute to elderly people's falls and the decline in activities of daily living (ADL) [4-5]. It is suggested that evaluating elderly people's executive function is helpful in evaluating their basic and applied movements. Among the executive function tests, the Wisconsin Card Sorting Test (WCST) is used in clinical settings, but if it can be administered relatively easily as Stroop tasks, it may be generally useful as a clinical evaluation tool for the elderly. Hasher et al. [6] used the WCST as a restraint function that caused the Stroop effect. A characteristic of the Stroop effect is that the output suppresses a response to easy stimulus, and the output is a task that responds to difficult stimulus. Additionally, the Stroop effect has a strong correlation to

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the Mini Mental State Examination dementia evaluation[7], and the decrease in restraint function is caused by cognitive function decline[8-9]. With the Stroop effect, rather than the naming of colors, the reading of the letters/words is fast[10]. Generally, a Stroop task has oral responses, and the required time shows the restraint reaction until the response. This type of restraint reaction occurs not only in oral but also in manual responses. In a clinical setting, making a subjective evaluation while observing a patient's behavior is common. It is suggested that quantitatively evaluating non-fluent movement is important in investigating hindrances in behavioral actions.

This study focused on the usefulness of the evaluation of the Stroop effect during sorting movements. In our daily actions, the microslip phenomenon often occurs, such as hesitating behavior, the trajectory of our movements, and changes in the shape of our hands[11]. Criteria of the microslips is "Hesitations", "Trajectory Changes", "Hand Shape Changes", and "Touches and Take/Gives". In the Stroop task in this study, the degree of executive function is not limited to required time. In this way, it is possible to demonstrate movement patterns as a microslip phenomenon.

The goals of this research were to verify [1] the differences between the oral classification and manual classification[2], the correlation between the time required for a task and the number of microslips, and [3] the differences between the young group and the middle-aged group in a manual Stroop task.

Methods

1. Experiment 1: The differences between oral classification and manual classification

1) Subjects

The subjects were 16 normal, healthy adults (aged 35.5 ± 10.1). We received written consent from the subjects, explaining the purpose of our research both verbally and in writing. Our research was carried out with the approval of the Medical Ethics Committee of Kanazawa University (approval number: 353).

2) Classification Cards

The classification cards were composed of the following four varieties: 16 black-ink word cards (red: 4; blue: 4; yellow: 4; green: 4), 16 colored color cards, 32 incongruent color-word cards (Figure 1). The classification cards were arranged on a whiteboard in four-card columns and four-card rows. The cards were 6 × 6 square centimeter.

3) Experiment Setting

The subjects' measured posture was seated (Figure 2). Hand movements during the experiment were recorded with a video camera (Canon: iVIH R1).

4) Implementation

The methods involved orally sorting (oral sort) and manually sorting (manual sort) the classification cards. The oral sort was 1) Word Cards: Word Reading, 2) Color Cards: Color Naming, 3) Color-Word Cards: Color Naming, and 4) Word-Color Cards: Word Reading. The manual sort was 1) Word Card: Sort by Word, 2) Color Cards: Sort by Color, 3) Color-Word Cards: Sort by Color, and 4) Word-Color Cards: Sort by Word. The instructions were to call the color or word of the cards, or put them in the classification boxes by hand.

5) Analyzing Method

The time required for task execution was measured by a stopwatch from the video recording of the subjects' vocalizations and movements. The measurement was performed by two occupational therapists, who determined the average required time.

6) Statistical Processing

The Stroop interference rate[12] was calculated according to the calculation methods of Hakoda et al (Stroop interference rate = ((3) required time of the color-word cards − (2) required time of color cards) / (2) required time of the color cards × 100). The comparison of manual sorting and oral sorting was tested by a two-way analysis of variance. Additionally, to clarify the presence or absence of interaction between the two tasks, as a secondary test, we performed multiple comparisons, making a Bonferroni adjustment to a paired t-test. For the comparison of the young group and the middle-aged group, an unpaired t-test was performed. The significance levels were all less than 5%.

2. Experiment 2: Differences among tasks and age group in manual sorting

1) Targets

There were 30 targets in the young group (ages 20 to 39) and 30 targets in the middle-aged group (ages 40 to 59); all subjects were normal, healthy adults, and all were right-handed. The average age in the young group was 30.2 ± 4.6, and the average age in the middle-aged group was 49.3 ± 6.0. We received written consent from

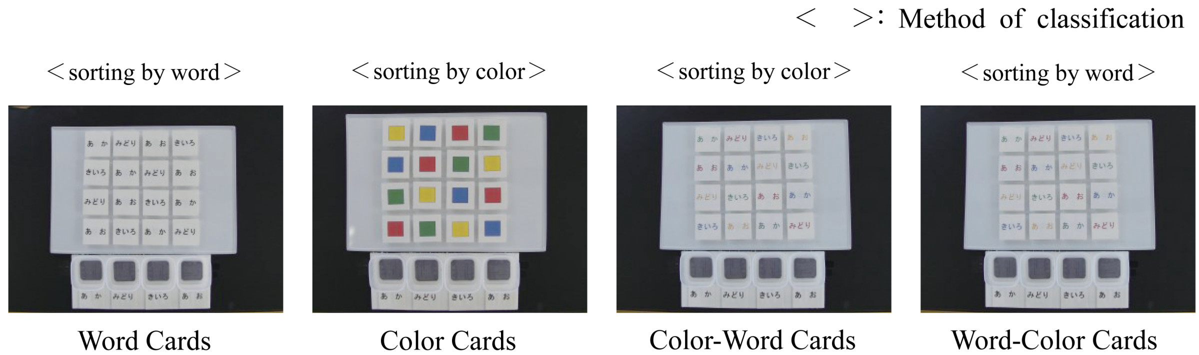

Figure 1. Sorting Card
The classification cards are composed of the following four varieties: 16 black-ink word cards (red: 4; blue: 4; yellow: 4; green: 4), 16 colored color cards, 32 incongruent color-word cards.

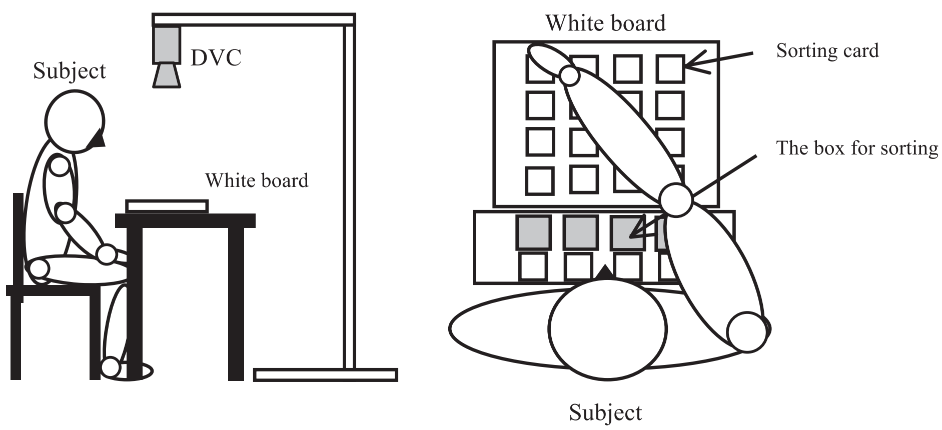

Figure 2. The setting of the experiment design
The subjects' measured posture is seated. Hand movements during the experiment are recorded with a video camera.

the subjects, explaining the purpose of our research both verbally and in writing. Our research was carried out with the approval of the Medical Ethics Committee of Kanazawa University (approval number: 353).

2) Classification Cards

The classification cards are the same as used in Experiment 1.

3) Experiment Setting and Methods

The experiment setting and methods are the same as in Experiment 1 (Figure 2).

4) Analysis Methods

The evaluation items measured the required time and the number of microslips. The microslip calculation was performed by two occupational therapists and the inter-rater agreement was determined by the kappa coefficient.

5) Statistical Processing

The comparison of manual sorting and oral sorting was tested by a two-way analysis of variance. To clarify the presence or absence of interaction between the two tasks, as a secondary test, we performed multiple comparisons, making a Bonferroni adjustment to a paired t-test. For the comparison of the young group and the middle-aged group, an unpaired t-test was performed. The significance levels were all less than 5%. For the correlation coefficient between the time and the number of microslips, Spearman's rank correlation was calculated. The Stroop interference rate [12] was calculated according to the calculation methods of Hakoda et al. [12].

From the calculated Stroop interference rate, a paired t-test was performed comparing manual sorting and oral sorting tasks, with a Bonferroni adjustment. Again, for the comparison of the young group and the middle-aged group, an unpaired t-test was performed. The significance levels were all less than 5%. The statistical analysis software SPSS (Version 20) was used during the statistical processing.

Table 1. The average of required time for oral sorting and manual sorting

	oral sorting	manual sorting
word cards	7.7 ± 0.5	21.0 ± 3.3
color cards	9.9 ± 0.6	19.2 ± 2.0
color-word cards	15.3 ± 1.4	25.7 ± 6.5
word-color cards	10.0 ± 0.6	19.7 ± 4.1

(seconds)

In the comparison of time among tasks, the required time for color-word cards was significantly slower than the rest of the cards（p < .05）. As with the oral sorting, there was a significant delay（p < .05）with color-word cards compared to the other cards in manual sorting.

Results

1. Comparison of oral sorting and manual sorting（Experiment 1）

The average of required time for oral sorting was 7.7 ± 0.5 seconds for word cards, 9.9 ± 0.6 seconds for color cards, 15.3 ± 1.4 seconds for color-word cards, and 10.0 ± 0.6 seconds for word-color cards（Table 1）. In the comparison of time among tasks, the required time for color-word cards was significantly slower than the rest of the cards（p < .05）. The average of required time for manual sorting was 21.0 ± 3.3 seconds for word cards, 19.2 ± 2.0 seconds for color cards, 25.7 ± 6.5 seconds for color-word cards, and 19.7 ± 4.1 seconds for word-color cards（Table 1）. However, as with the oral sorting, there was a significant delay（p < .05）with color-word cards compared to the other cards in manual sorting. The Stroop interference rate was significantly higher in the oral sorting tasks（54.9%）compared to the manual sorting tasks（34.3%）（p < .05）（Figure 3）.

2. Comparison of required time and the number of microslips in manual sorting（Experiment 2）

We confirmed that there was a significant time delay with color-word cards compared to the other cards（p < .05）.

There were 1.4 microslips for the word cards, 1.5 for the color cards, 6.5 for the color-word cards, and 2.8 for the word-color cards. The number of microslips increased significantly with the color-word cards, compared to the other cards（p < .05）（Figure 4）.

A high correlation coefficient between the required time and the number of microslips was confirmed with（r = .72）for word cards,（r = .65）for color-word cards, and（r = .49）for word-color cards（p < .05）. The color cards（r = .39）had a low correlation（p < .05）（Figure 5）.

3. Comparison of the young group to the middle-aged group in manual sorting（Experiment 2）

There was no significant difference between the groups in the required time for word cards and color cards. However, the required time for color-word cards among the middle-aged group（28.7 seconds）was significantly slower compared to the young group（23.1 seconds）（p < .05）. In the word-color cards a significant difference was confirmed between the middle-aged group（21.4 seconds）and the young group（19.2 seconds）, with a significant delay in the middle-aged group（p < .05）.

There was no significant difference between the groups for the number of microslips in the word cards and color cards. However, a significant increase in the number of microslips in the color-word cards was confirmed for the middle-aged group（7.6 times）, compared to the young group（5.4 times）（p < .05）. A significant difference was also confirmed in the word-color cards, with the number of microslips increasing in the middle-aged group（3.2 times）compared to the young group（2.4 times）（p < .05）（Figure 6）.

The Stroop interference rate in manual sorting was 27.9% for the young group and 47.7% in the middle-aged group, with the Stroop interference rate significantly

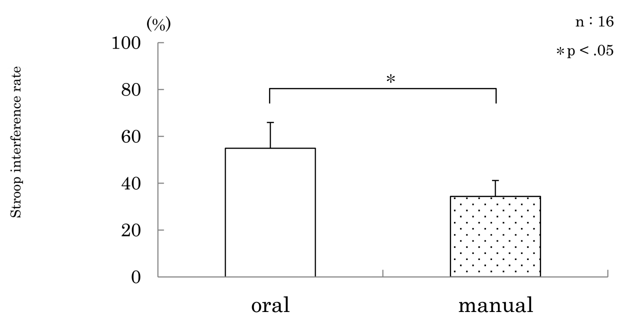

Figure 3. Comparison of the oral task and the manual task（Stroop interference rate）

The Stroop interference rate was significantly higher in the oral sorting tasks（54.9%）compared to the manual sorting tasks（34.3%）.

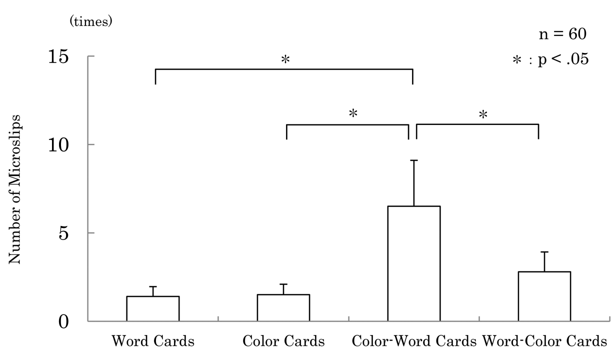

Figure 4. Comparison between each the tasks（Number of microslips）

The average number of microslips increased significantly with the color-word cards, compared to the other cards.

higher ($p < .05$) in the middle-aged group, and with the middle-aged group experiencing word interference much more strongly than the young group (Figure 7).

Consideration

In Experiment 1, the differences in oral sorting and manual sorting were examined. In Experiment 2, the differences in the presence of the Stroop effect in manual sorting between the two age groups were examined.

1. Reaction differences in oral sorting and manual sorting

To evaluate the inhibitory reaction caused by the

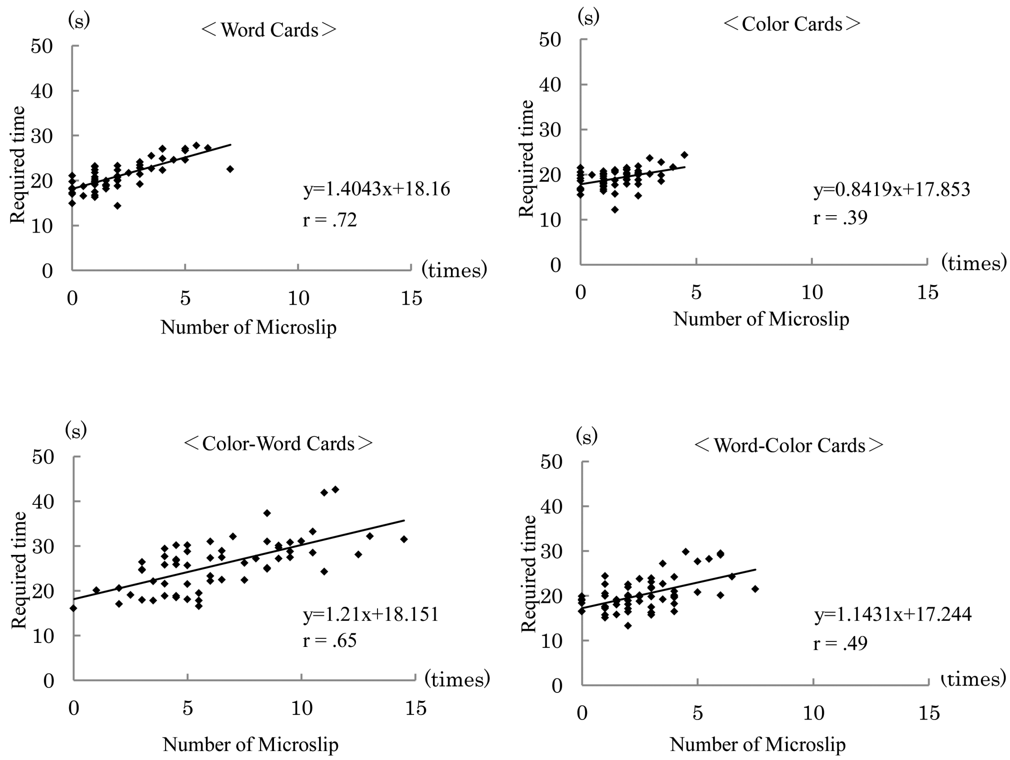

Figure 5. The correlation coefficient between the required time and the number of microslips
A high correlation coefficient between the required time and the number of microslips was confirmed with ($r = .72$) for word cards, ($r = .65$) for color-word cards, and ($r = .49$) for word-color cards ($p < .05$). The color cards ($r = .39$) had a low correlation ($p < .05$).

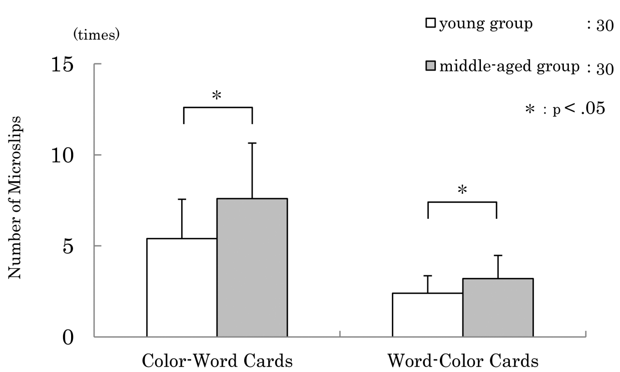

Figure 6. Comparison between the young group and the middle-aged group (Number of microslips)
The average number of microslips increasing in the middle-aged group compared to the young group.

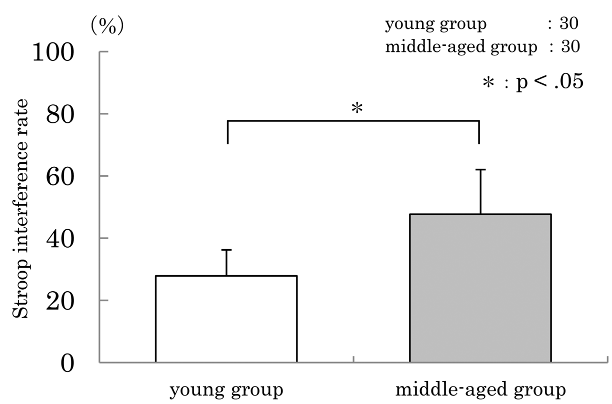

Figure 7. Comparison of the young group and middle-aged group by the manual task (Stroop interference rate)
The Stroop interference rate in manual sorting was 27.9% for the young group and 47.7% in the middle-aged group, with the Stroop interference rate significantly higher in the middle-aged group, and with the middle-aged group experiencing word interference much more strongly than the young group.

Stroop effect, the required time of the tasks was divided by the Stroop interference rate. The Stroop interference rate was significantly higher in oral sorting than in manual sorting. Oyama [13] states that oral reactions are slower than manual reactions, such as pushing buttons. The Stroop interference-rate data from this study confirms that oral has a higher interference rate value than button pushing, indicating that oral responses are slower than movement responses. That is, we have interpreted that Stroop interference rate of movement responses are lower than oral.

2. The Relationship between Required Time and the Number of Microslips

This study also confirmed the difference between required time and microslips in sorting tasks. A high correlation between required time and microslips was confirmed in some task. Suzuki et al. suggest that, regardless of the difficulty of the conditions, the number of microslips increases with the time required to complete the task [14] . In other words, in addition to the difference in required time, the increase or decrease in the number of microslips will be one indicator of inhibitory function evaluations. Suzuki [14] points out the relationship between the environment and the agent/actor in the occurrence of microslips, and that the frequency of microslips increases when factors unnecessary for accomplishing the task are added. We considered a low correlation that relationship of the subjects and color was small.

3. The difference in movement reactions in the young group and middle-aged group

There is a tendency for the inhibition of unnecessary information to wane as people age [15] . The difficulty with appropriately selecting specified information was demonstrated by the difference in time between the young group and the middle-aged group, with the task of distinguishing between the color-word cards and word-color cards.

Suzuki et al. point out that in movement selection, the strength or weakness of the task influences the occurrence of microslips [14] . Visual information when sorting the word cards and color cards may be understood as a single piece of information that does not affect judgment. However, for mixed color and word information, when one attempts to choose a color, the word information inhibits the color information and the delay in judgment during sorting manifests as a hesitation in hand movement, and increases the occurrence of microslips. Thus, it is possible that the decline of inhibitory functions with age [8] has an effect on the occurrence of microslips.

The Stroop interference rate is high early in life, and with the development of the inhibitory functions from around 7 to 10 years of age to around 17 years of age, it tends to decrease [16-19] . After that, the Stroop interference rate stabilizes during adolescence [16-17] . Sasaki and Hakoda [20] completed Stroop tasks with elderly people and children, and showed that the elderly subjects had a higher Stroop interference rate. As for the delayed reaction time that comes with aging, there is markedly more delay in choice reactions than in simple reactions [13] . In other words the results of this research, which show a higher Stroop interference rate in the middle-aged group than the young group, showed that the Stroop interference rate increases with age. Additionally, the Stroop interference rate may become an indicator for the evaluation of inhibitory functions with aging.

The significance of this study is the possibility of the Stroop task with age. Elderly is easy to accept the simple things than complex things. Elderly is easy to refuse when introducing new things. We believe that a simple assessment scale is required in the inhibitory function evaluation for the elderly.

Limitations and Future Research

This research is limited in that there were only 30 young people and 30 middle-aged people as the targets, and so it is possible that the research results are biased and cannot be considered as data representing an entire age group. In future research, it will be necessary to collect more data on required time for oral sorting and for manual sorting, and to verify the correlation between the Stroop effect in oral tasks and manual tasks.

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仕分け動作によるストループ課題の有用性
- 加齢によるマイクロスリップ数とストループ干渉率 -

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要　旨

本研究の目的は，口頭と動作分類による課題遂行の差異，所要時間とマイクロスリップ数の相関性，若年群と壮年群のストループ干渉率の差異を検証することである．対象者は実験1が16名（21～55歳），実験2が若年群30名（20～39歳）と壮年群30名（40～59歳）の健常成人であった．4種類の分類カード16枚を使ってそれぞれを分類した．実験1では口頭と動作の所要時間とストループ干渉率を算出し，実験2では動作での所要時間，ストループ干渉率，マイクロスリップ数を算出し，口頭と動作間の比較，若年群と壮年群間の比較を行った．ストループ課題を口頭と動作で行った場合のストループ干渉率の比較では，口頭が動作よりも有意に高かった（p<.05）．若年群と壮年群間の比較では，壮年群が若年群よりも口頭および動作ともに有意にストループ干渉率が高かった（p<.05）．マイクロスリップ数は，壮年群が若年群よりも有意に増加した(p<.05)．所要時間とマイクロスリップ数の相関関係は，4種類の分類カードで高い相関を認めた（p<.05）．本研究での選択反応によるストループ干渉率は，動作よりも口頭の方が高いことが確認され，選択反応は単純反応と同様に発声による反応が動作よりも遅いことが示唆された．マイクロスリップ数は所要時間の遅延とともに増加し，マイクロスリップ数と所要時間の相関が示唆された．